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Title: Statistical Hauser-Feshbach model calculation for (α,n) reaction cross section and discrete level population

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Statistical Hauser-Feshbach model calculation for (α,n) reaction cross section and discrete level population

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We calculate the α-particle induced reactions on ^{17,18}O, ^{19}F, and ^{23}Na, in the energy range $0 \leq E_\alpha \leq 10$ MeV, with a particular attention to the branching ratios of populated discrete levels in the (α,n) channels. Since there are too many open channels to employ the R-matrix theory, we apply the statistical Hauser-Feshbach model to calculate these reaction cross sections and branching ratios. The branching ratio is defined as

$$b_n = \frac{\sigma_n}{\sum_i \sigma_i + \sigma_c} \ , \tag{1}$$

where σ_n is the n-th level production cross section after the neutron emission, and σ_c is the production of the continuum state. In the cases of our target nuclei and the energy range of interest, the residual nuclei of the neutron emission channel are always in their discrete states, so that σ_c can be negligible.

The statistical Hauser-Feshbach code CoH$_3$ [1, 2] is used to calculate the α-particle induced reaction. The optical potential parameter for the α-particle is taken from the work by Avrigeanu et al. [3]. The Koning-Delaroche optical potential [4] is applied to the neutron and proton channels. Because the (α,d) cross section is too small in the case of this study, we neglected the deuteron channel. Properties of the discrete levels (excitation energy, spin, and parity) are taken from RIPL-3 [5], with some minor modifications based on the most recent ENSDF database [6]. All the other model parameters, such as the level density and the γ-ray strength functions, are the default built-in parameters in CoH$_3$. At higher incident energies, a emitted proton sometimes leaves the residual nucleus in its continuum state. Generally speaking, however, the excitation energy is still not so high. The branching ratios are mainly determined by the optical model transmission coefficients and the spin and parity of discrete levels. We also note that the calculated ratios are relatively robust, although the absolute cross sections of discrete level production could have some uncertainties due to the optical potential parameters employed.

The calculated (α,n) cross sections for ^{17,18}O, ^{19}F, and ^{23}Na are shown in Fig. 1. Because the statistical model does not predict any resonance structure, these cross sections are understood to be energy-averaged. Besides the (α,n) cross section, some reaction channels have comparable cross sections to (α,n). They are ^{17}O(α,nα) and ^{19}F(α,p), which are also shown in this figure.

The calculated branching ratios for ^{17,18}O, ^{19}F, and ^{23}Na are shown in Fig. 2. Wilson et al. [7] performed the similar calculations with the Hauser-Feshbach code GNASH [8, 9] in the past. There is another model prediction by Lessor and Schenter [10], which is based on some available experimental data. We compare our calculated results with these former predictions in Figs. 3–6.

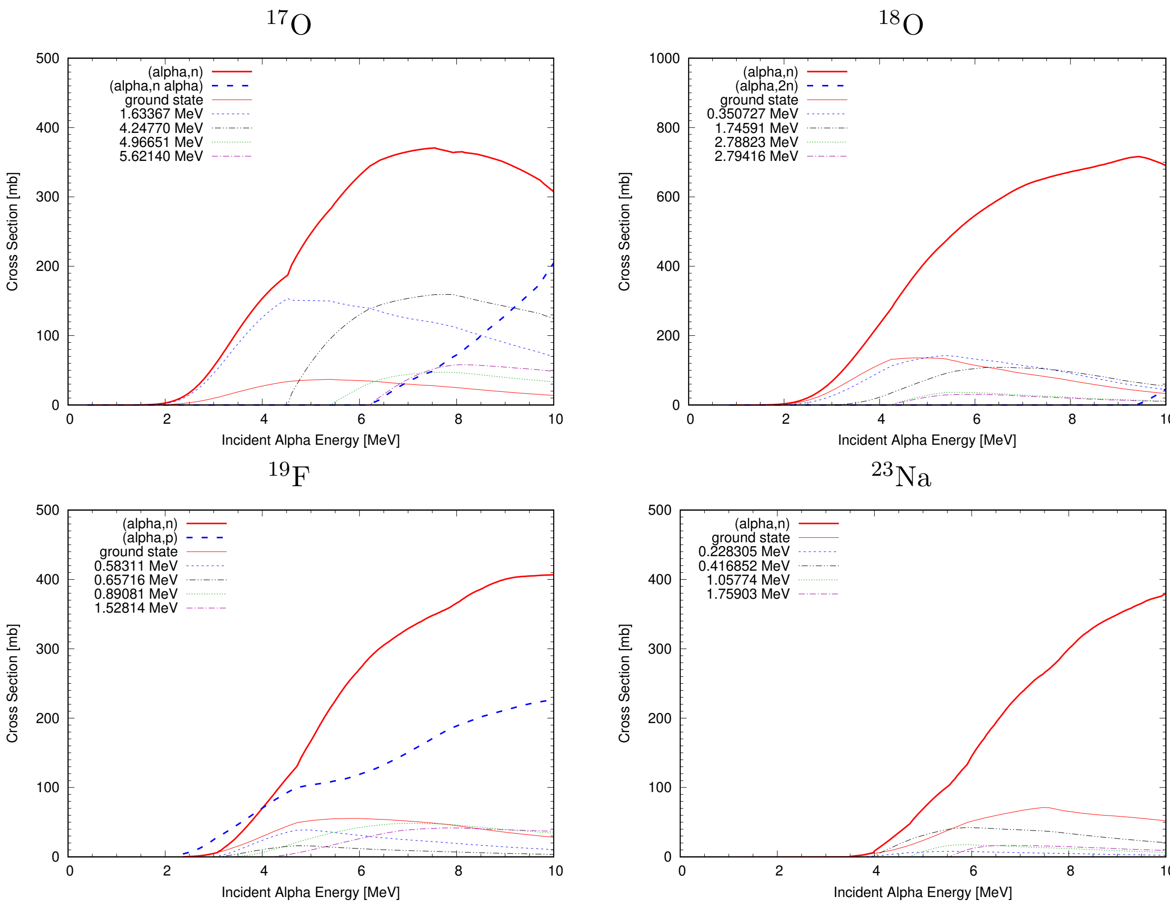

Figure 1: Calculated (α,n) reaction cross sections for ^{17,18}O, ^{19}F, and ^{23}Na, shown by the thick curves. The partial cross sections for the first five levels, σ_n, $n = 0$–4, are shown by the thin curves.

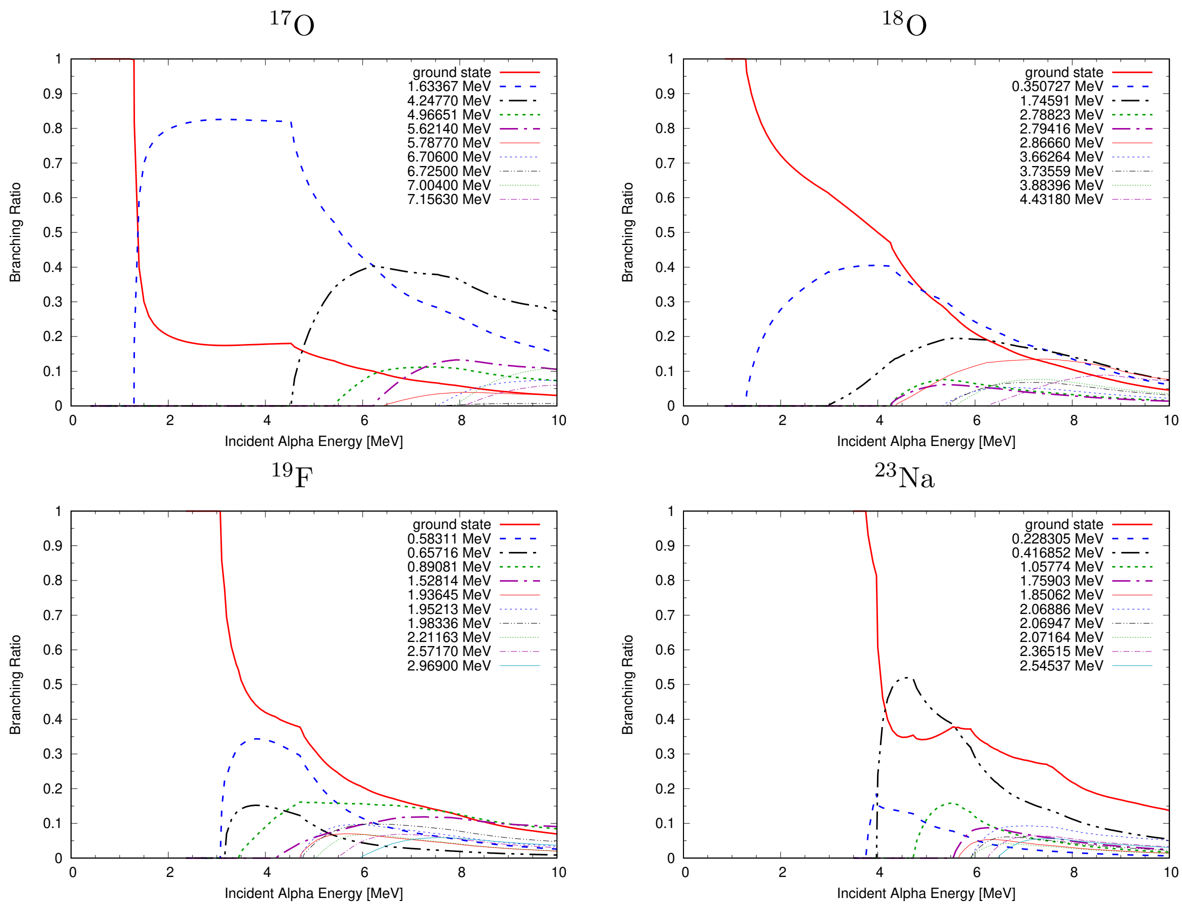

Figure 2: Calculated branching ratios for the ^{17,18}O, ^{19}F, and ^{23}Na(α,n) reactions to the discrete states in ^{20,21}Ne, ^{22}Na, and ^{26}Al.

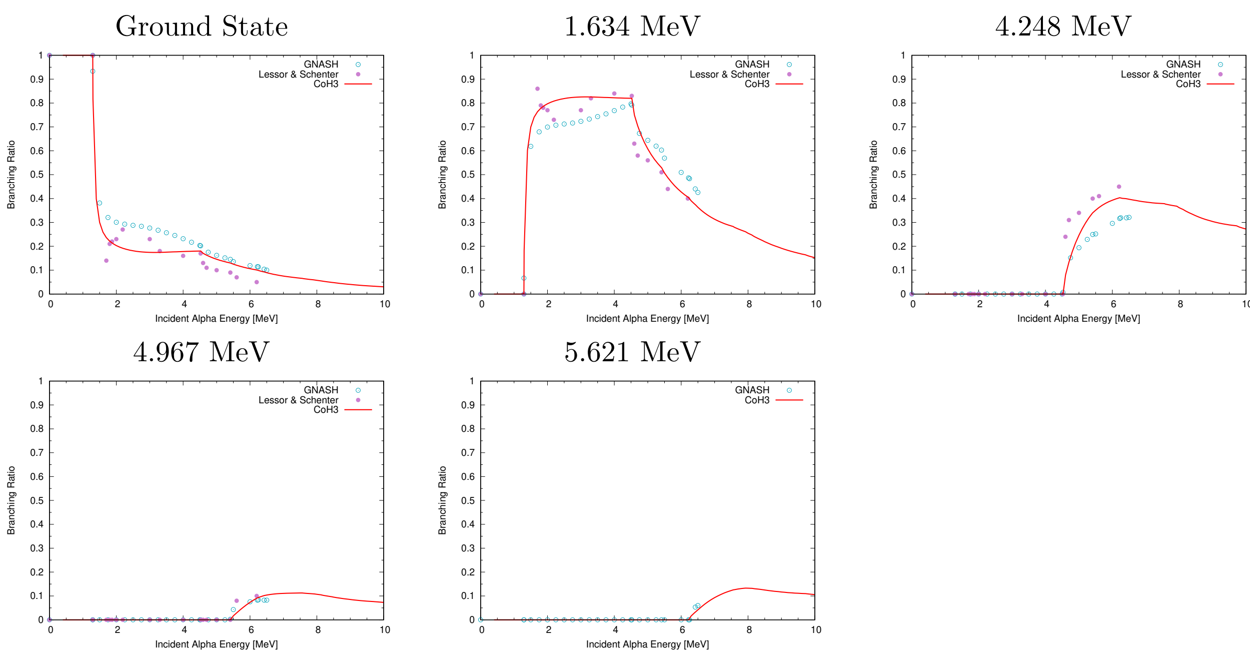

Figure 3: Calculated branching ratios of the ^{17}O(α,n) reaction to the discrete states in ^{20}Ne.

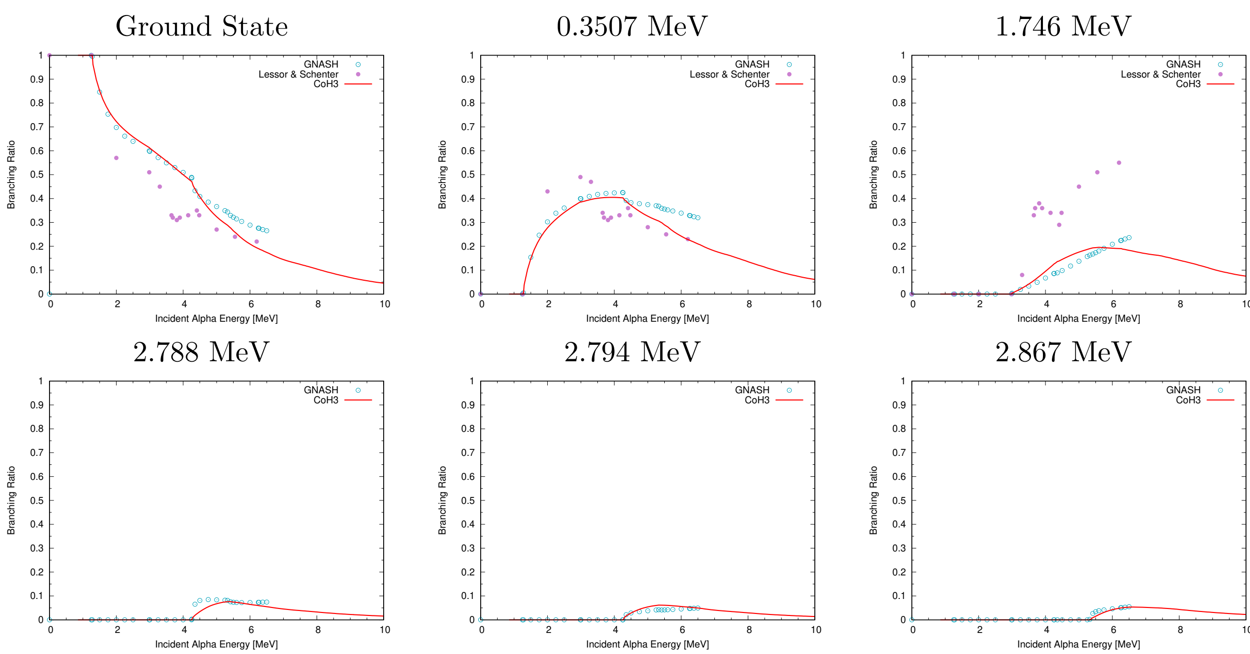

Figure 4: Calculated branching ratios of the ^{18}O(α,n) reaction to the discrete states in ^{21}Ne.

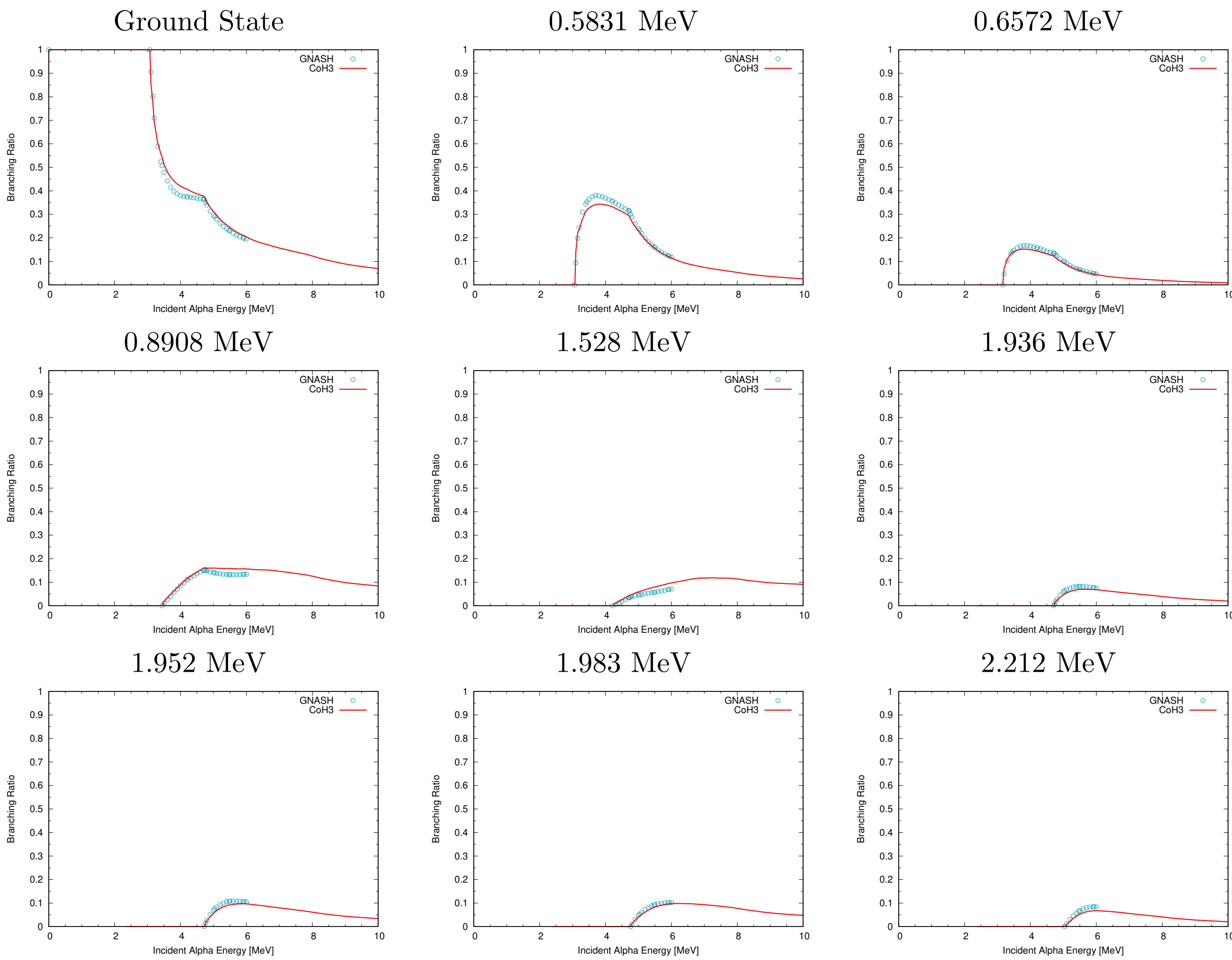

Figure 5: Calculated branching ratios of the $^{19}F(\alpha,n)$ reaction to the discrete states in ^{22}Na.

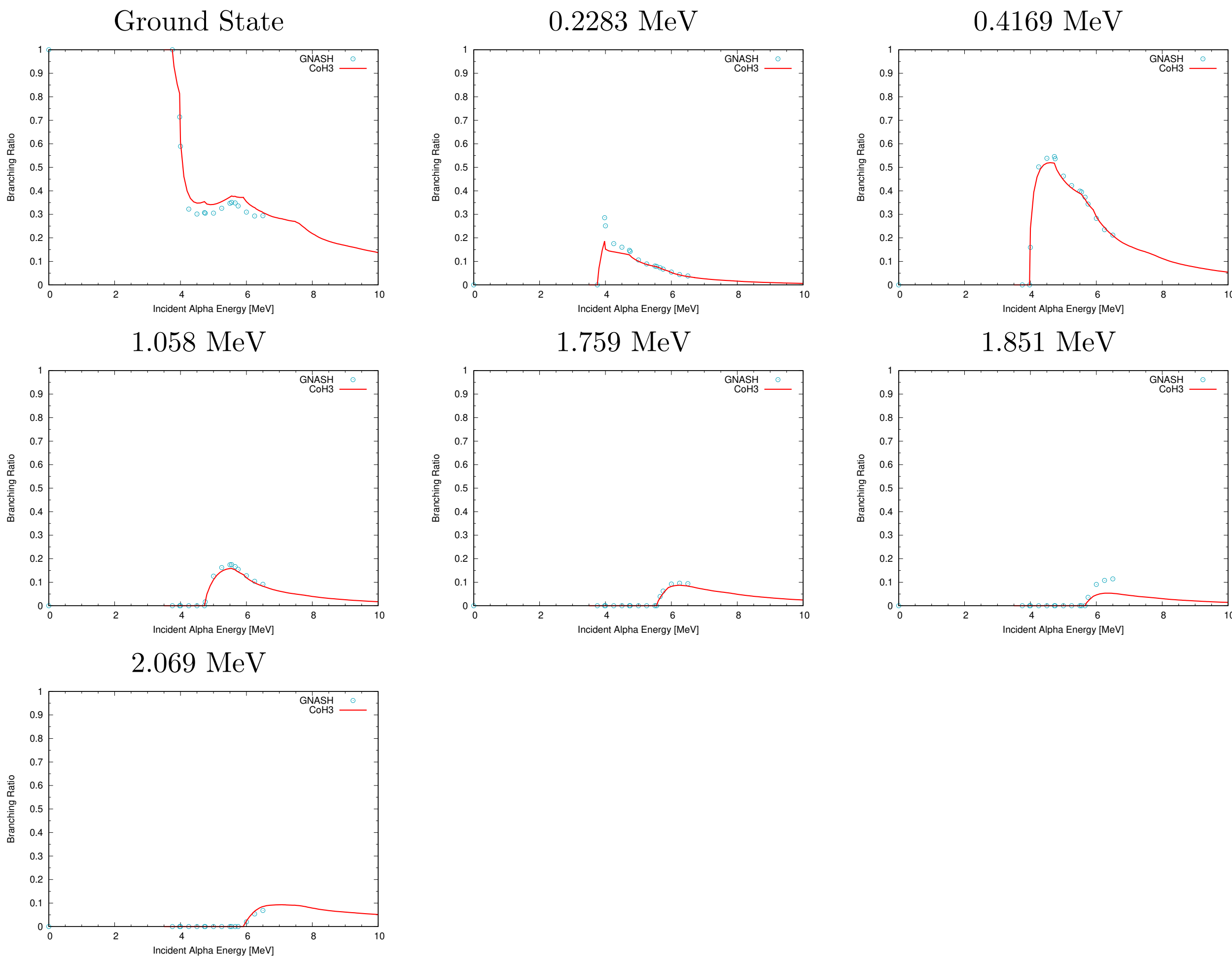

Figure 6: Calculated branching ratios of the ^{23}Na(α,n) reaction to the discrete states in ^{26}Al.

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